THE MERIT ORDER EFFECT OF RENEWABLE ENERGY SOURCES IN THE LONG RUN

Felix Müsgens, Brandenburg University of Technology, felix.muesgens[at]b-tu.de
Thomas Möbius, Brandenburg University of Technology, thomas.moebius[at]b-tu.de

Overview

Increasing shares of intermittent electricity generation from renewable energy sources (RES) such as wind and photovoltaics bring structural changes to many electricity markets. Historically, a flexible supply side (mostly either thermal power stations or hydro storage) balanced a time varying demand. Today, increasing shares of intermittent RES generation depend on meteorological conditions (e. g. wind conditions or solar irradiation). Hence, the availability of these generation capacities on the supply side is both intermittent and uncertain. These structural changes fundamentally influence the electricity market and change the resulting price structures.

Our paper analyses the effect of intermittent RES feed-in on wholesale electricity prices. We are interested in the resulting market equilibrium prices, both with respect to resulting price averages as well as volatility. Starting from an over-simplified textbook example, where RES influence neither the annual average electricity price nor the volatility (as long as fluctuations can be forecasted), we increase the complexity of the analysis to make it more realistic. We find that both increasing the share of RES to levels where they have to be curtailed as well as including uncertainty in the model increase wholesale price volatility.

This paper is an improved version of the paper Möbius, T. und Müsgens, F. (2017).

Methods

We develop and apply an electricity market investment and dispatch model. The model is formulated as a non-linear optimization problem (NLP) which maximizes social welfare in the electricity system. This is in accordance with a perfectly competitive market outcome. Key constraints are: generation has to equal demand in every hour, generation cannot exceed installed capacity, generation of running capacity must be above partial load requirement, and several other conditions capturing central techno-economic aspects of power systems. In order to account for uncertainty in the wind generation, we develop a stochastic programming model with recourse.

We use different versions of the model to analyse the effect several key aspects of an electricity system have on wholesale electricity prices. In particular, starting from a simple model, we include more and more equations to draw a more realistic picture. Thus, we are able to isolate the effects of RES curtailment (whenever RES generation exceeds consumption), start-up requirements and uncertainty. Start-up restrictions are modelled with sveral equations, e. g. specifying that production in any period t cannot exceed startet-up capacity in period t-1 plus new start-ups in period t (minus shut-downs in t). Uncertainty is an addtitional methodological focus in our paper, as the limited forecasting accuracy is a central element of intermittend generation, especially wind. We include this with a set of wind realization scenarios within a set of possible wind years. Thus, both the investment decision for installed generation capacities as well as the decision for unit commitment underly imperfect information concerning the wind generation. As we use an integrated model architecture to implement our scenarios, we are able to receive a (partial) market equilibrium. Furthermore, we increase the share of intermittent wind generation in different model runs.

Results

We find that the effect of intermittent RES on wholesale prices in market equilibrium is not as clear-cut as some people may think. The result in the over-simplified textbook environment, where intermittent RES neither influence average prices nor price volatility, may be surprising at first glance. However, the intuition is simple: in equilibrium, wholesale prices have to cover total costs of thermal capacity. As long as investment in thermal capacity is needed, and thus has to be financed, prices (and price spikes) must be sufficiently high. As investment costs of thermal generation are independent of the wind capacity, necessary price levels are the same regardless of the amount of wind capacity in the system.

This changes when the model is set-up in a more realistic way. We find that both modelling RES-curtailment as well as uncertainty increase wholesale price volatility. In hours of wind curtailment, electricity prices are driven

towards zero (the marginal cost of wind). This increases the volatility as such price levels do not occur without wind capacity. The explicit modelling of uncertainty also increases price volatility. The reason is that the less likely a peak period becomes, the higher its price must be to cover total costs of capacities.

Conclusions

This paper analyses the impact of increasing shares of intermittent RES on the electricity market, particularly on the electricity wholesale prices. Regarding different shares of wind generation we identify (partial) market equilibria. Thus, we are able to analyse electricity prices which are based on a total cost approach. We show that the variance of electricity prices is increased by fluctuating RES. This is caused by an increase in startup activities as well as the occurance of wind curtailment. The uncertainty concerning realisations of wind feed-in increases the effect.

Literature

Möbius, T. und Müsgens, F. (2017): 'Electricity market equilibria and intermittent re-newables — A stochastic approach', IEEE Conference Proceedings EEM 2017, DOI: 10.1109/EEM.2017.7981988